Soc Assignment E1.1B Generation of acoustic waves

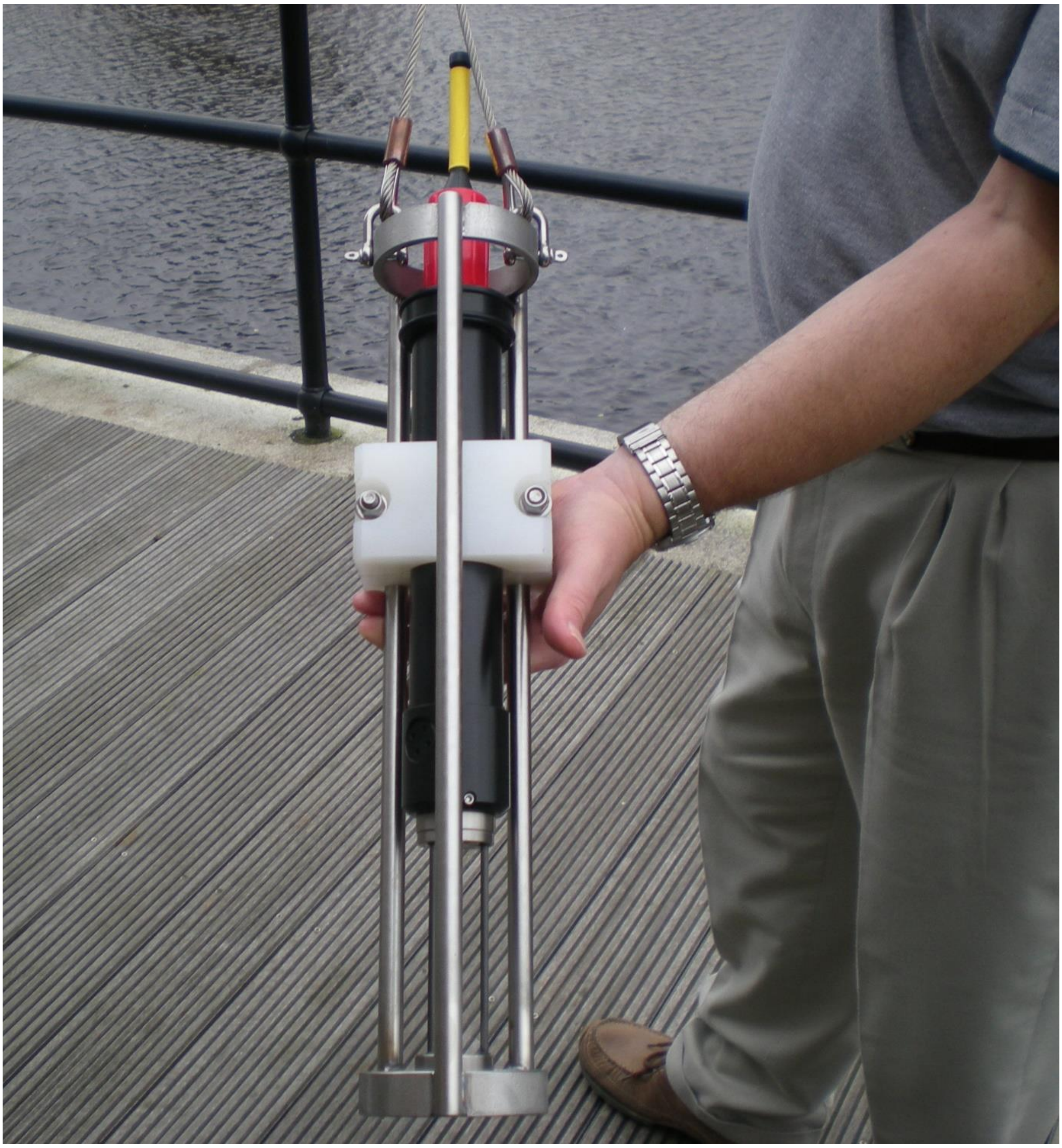

Figure 1 Valeport SVP (http://www.demetra5.kiev.ua/ru/catalog/profilografi-skorosti-zvuka/miniSVP)

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Introduction

For the education course Ocean technology of the maritime institute Willem Barentsz we had to do three SOC assignments during the internship. I choose for this subject because it is the biggest element in surveying and during my internship I came a lot in contact with acoustic waves generators. And most of the information is very useful to know during your work activity's.

Summary

Sound

The Definition of sound is as follows: transmitting vibrations of any frequency. Humans can pick up on those vibrations if the frequency of the vibration is within 20HZ and 20 KHz. These vibrations can be transmitted through every medium such as Gas liquid or solid but cannot be transmitted through vacuum. Each vibration is called a wave and how many waves the are per second is called the frequency. Sound Is the changing of the ambient atmospheric pressure whether this is detectable by humans or not. The source of sound Is almost always a vibrating object except for the sound generated by an explosion this is caused by the very fast expanding of gases. Due to those vibrations of the object it changes the pressure around the object from high to low pressure and this be given on the other parts of the medium it is the same behaviour as a wave in the sea. A sound wave can bend around another object this is called diffraction. It also can be reflected from an object this is called reflection. When changing from medium the sound wave can also go to another direction.

The international unit to measure pressure in is called Pascal (Pa). 1Pa equals 1newton per square meter.

A sound was having an amplitude and a wavelength. Besides this the sound wave is sinusoidal and longitudinal pressure wave.

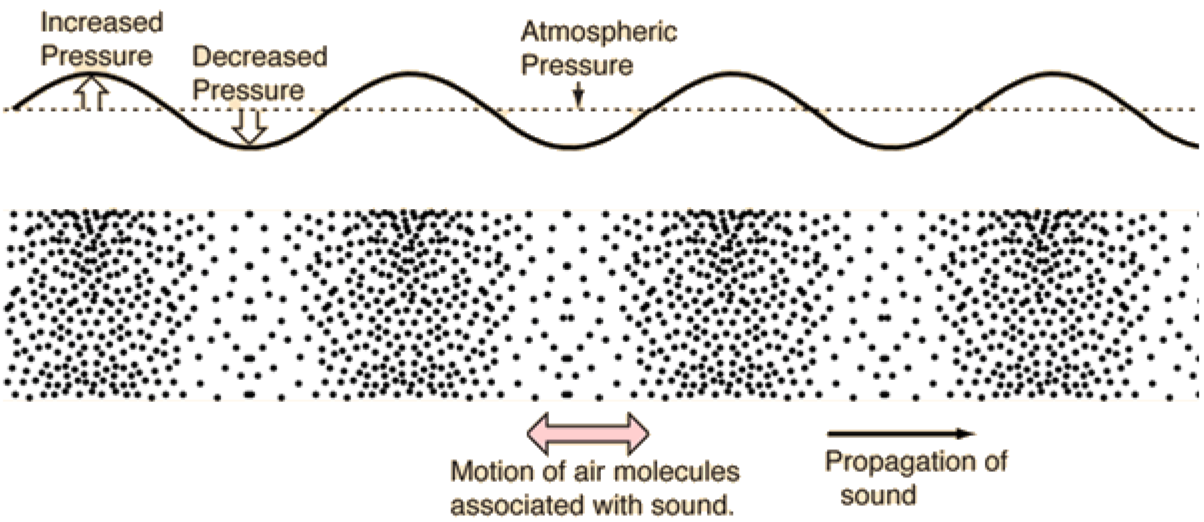

Figure 2 sound wave (http://hyperphysics.phy-astr.gsu.edu/hbase/Sound/tralon.html)

Frequency

For remote sensing in a water environment the usage of sound waves is ideal because some types of sound waves can travel a huge distance before significant attenuations this is different compared to light and radio waves who lose most of their initial energy after only a couple of meters. But not all sound waves are usable for traveling larges distances because this all depends on their frequency how higher the frequency how quicker the attenuation is and how lower the frequency how less effect the attenuations has. For example, a sound wave from a standard 12KHZ sonar loses around half of its initial energy after 3000meter.

Wavelength

A wavelength is defined as the peak of one wave to the next peak of a sound wave, or any other corresponding point of a sound wave till the next. the wavelength is defined by the Greek letter lambda. With this and the frequency the speed of the soundwave can be defined by the formula

$$\lambda = \frac{V}{f}$$

Where:
Λ=wavelength
V=speed of the wave
f =frequency

the speed for the sound in the air is around 340 m/s when the air has a temperature of 20 degrees Celsius.

Amplitude

The amplitude is the distance from the middle to a peak of a sound wave and indicates how much acoustic energy there is in the sound wave which indicates how loud the sound is. This means if the amplitude is bigger the sound will be louder.

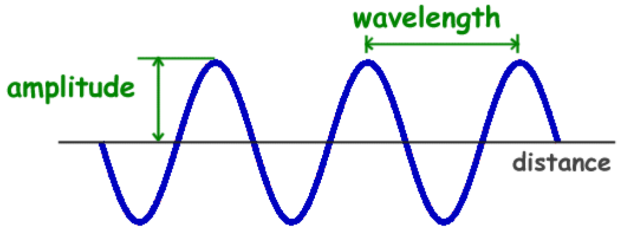

Figure 3 Sound wave (http://www.ducksters.com/science/physics/properties_of_waves.php)

Speed of sound

The sound speed depends on al lot of different factors like what kind of medium is the sound traveling through and in which state is this medium: gas, liquid or solid. This narrows down to the three-main variable namely pressure, temperature or density.

Which gives the following formula for the speed of sound in air:

$$c = \sqrt{y * \frac{RT}{M}}$$

-c =speed of sound [m/s, which corresponds to dry air to around 330m/s

-y=adiabatic gas constant, $y = \frac{Cp}{Cv}$ is the specific heat ratio what corresponds for dry air to 1.41.

-R=is the gas constant, the general gas constant equals 8.3145J/ (mol K)

-T= the absolute air temperature [k]

-M= molecular weight, the molecular weight of air equals 28.97g/mol

Because this formula is for air I cannot be applied on water because in water there are other factors that contribute to an accurate sound speed as well like salinity.
The formula for the speed of sound in water:

$$c = 1449.2 + 4.6T - 0.055 * T^2 + 0.00029 * T^3 + (1.34 - 0.01T) * (S - 35) + 0.016d$$

In this formula, the speed of sound is again c expressed in m/s. T is the temperature of the water in degrees Celsius. S stands for salinity in parts per thousands (‰) and d is the water depth in meters, this means if the water temperature rises the sound velocity goes up and when the salinity rises the sound speed goes up. The speed of sound in salt water is around 1500 meter per second.

Characterizing pressure of sound waves.

There are a couple of different ways to describe the pressure of sound waves namely:

-0-peak pressure.

-peak to peak pressure.

-root mean square pressure.

0-peak pressure is the same as the amplitude so from the mean to the peak.

Peak to peak pressure is the vertical difference between the lower peak and the upper peak this means in constant waves it is 2times the amplitude.
Root mean square pressure is defined by the square root of the average of the square of the pressure of the sound wave of a given duration

For defining the root mean square pressure there are four steps
First you must measure the pressure at a view points along the wave
Secondly you need to square the measured pressures
Thirdly is to take the average of those squared pressures
And fourth is to take the squared root of the average squared pressures.

All these three pressure are different indicators.

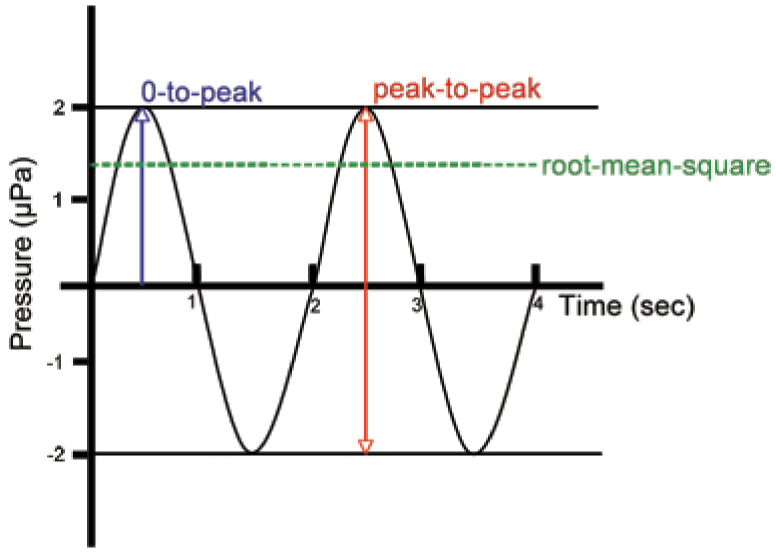

Figure 4 http://www.dosits.org/science/advancedtopics/signallevels/

Intensity

The intensity is the average sound power this is the sound energy per unit time, transmitted through a unit area in the specific direction. The intensity is valued in watts per square meter. The magnitude of the intensity is also referred to as the intensity without specifying the direction where the sound is traveling to. Internationally the unit of intensity is referred to as decibel what is 1/10 of a bel what is a relative unit. The intensity is proportional to the square of the pressure so it can be calculated if the amplitude is known. With the following formula:

$$I = \frac{p^\wedge 2}{pc}$$

With p is pressure, ρ is the mediums density and c speed of sound

The sound pressure level in dB can be obtained by using the following logarithmic equation:

$$Sound\ Pressure\ Level = 10\log_{10}(\frac{p^2\ (root - mean - square)}{P^2(0)})$$

With p^2(0) as the square of the reference pressure in pascal.

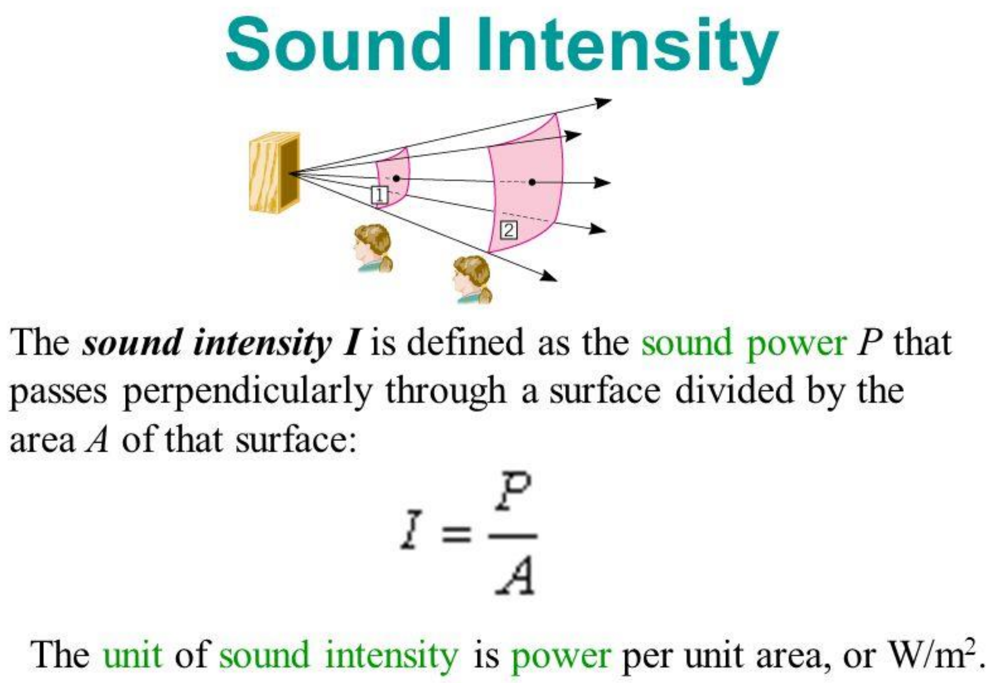

Figure 5 Intensity(http://slideplayer.com/slide/7655697/)

Source level

The source level definition as the amount of sound radiate by a sound source it is defined as the intensity at 1 meter distance of the source. because the intensity of sound is transmitted in a certain direction the source level can only be defined when the sound energy flows steadily away from the source and thus there should be no diffraction or reflection. the source level is also expressed in dB

For many larger sources, such as a ship at sea, the source level has then a Sufficient validity because of the wide range, but is not valid when too close, like one meter when it is inappropriate to Consider It Being a point source.

The formula of the source level is $SL = 20\log(P * r)$

In this formula, SL = source level, P = the pressure and r is the range in meter.

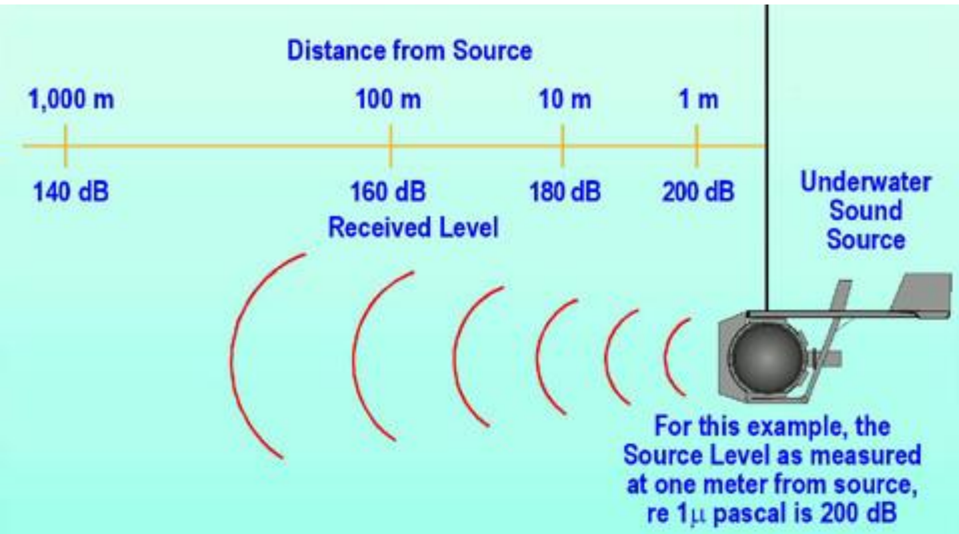

Figure 6 sourcelevel (http://www.surtass-lfa-eis.com/Terms/)

The sound velocity profiler

As mentioned before, for underwater measurement a lot of equipment are used that use sound therefor an accurate sound speed is necessary to have. This is where the sound velocity profiler comes in to the picture. depending on model they give an accurate sound speed for each couple of centimetres/meters and give an accurate mean value which can be applied to other measuring devices. The reason why a sound velocity profiler measures the sound speed with intervals is because the salinity, temperature and pressure are ever changing when you are going deeper. During my internship, I worked two different Sound Velocity Profilers one was from Valeport and one from AML. The AML was the most commonly used at Geoxyz.

The working principal of the sound velocity profiler is quite simple It is having a transducer that sends a sound pulse towards a metal reflecting plate at the bottom of the sound velocity profiler. The distance between the transducer and the metal plate is known and the time between receiving and sending out the pulse is known from this the sound velocity can be measured I combination with the depth of the Sound velocity profiler at that moment.

The formula is as follow: $c = \frac{d*2}{t}$

C= the sound velocity

D= the distance between transducer and the reflecting material

T= the time between sending and receiving the sound pulse

Figure 7 AML Base X2 Geosurveyor VIII

Acoustic wave generator

There are two main acoustic wave generators namely the transducer and the airgun. From these two option the transducer is the most used

Transducer:

A transducer is a transformer of energy is this case electricity to movement or the other way around. There is a multiple different transducer namely transducers that transform electricity to acoustic waves, transducers that transform acoustic waves to electricity and transducers that can do both.

To make the acoustic wave the transducer head needs to be underwater but it still needs to vibrate that is conceived due to a material that expands when it contacts electricity this material is inside the transducer and is under current from an AC Voltage source which makes the material expand in the same frequency as the current and this past on to the medium. There are three major groups of material that vibrate when it comes in contact witch an AC voltage. Piezoelectric, electrostriction and Magnetostriction.

Piezoelectricity

Piezoelectricity is accumulation of an electric charge inside of certain solid materials and therefor it is noted as electricity coming from pressure. There are a couple of materials capable of this effect such as:

- -Dihydrogen phosphate
- -Quartz
- -Lithium sulphate
- -Rochelle salt

Electrostriction

Electrostriction Is a property of all electrical non-conductors, or diel electrics that change their shape when they are put under effect of an electric field. There are not many materials that exhibit this trait but these are the most common:

- Lead magnesium niobate (PMN)
- Lead magnesium niobate-lead titanate (PMN-PT)
- Lead lanthanum zirconate titanate (PLZT)

Magnetostriction

Magnetostriction is quite like electrostriction but is more a charging due to the possible Magnetostriction materials do not change form or dimension till there saturation level is reached. The following materials are most common for Magnetostriction:

- -Nickel
- -Cobalt

Acoustic impedance

this material is surrounded by castor oil which has the same impedance values as sea water. The underside/head of this kind of transducer also has the same impedance values as sea water but is only more solid for instance PC rubber has the same impedance values as seawater. For the casing of the transducers normally bronze is used because it has a totally different impedance value and therefore reflect the sound pulse through the head of the transducers. To calculate the acoustic impedance the following formula is used:$Acoustic\ impedance = \rho * c$

ρ= is the density of the material (Normally around 1030kg/m^3)

c=the speed of sound (commonly around 1500 m/s)

the generated soundwave has the same frequency as the generated pressure wave but only it has a 90degrees fase change.

Airgun

The airgun is developed as a safer option than blowing up TNT below water what once was commonly accepted to use but the airgun still use the same Princip's namely making an underwater explosion in the airgun case exploding compressed air bubbles. These exploding compressed air bubbles are created by the airgun through releasing compressed air underwater. The wave this generates has a low frequency but a lot of power this makes it able for other ships to pick up to the signal even when they are 900nauticalmiles away. These waves are used to localise oil and gas reserves far below the seabed and there from need a high penetration and low amount of detraction so this is ideal for a high powered low frequency sound wave. The big problem is that scientist cannot get much data out of 1 big sound wave therefor scientist came up with the idea to make a tuned airgun array this generates a couple of sound waves of careful specified size but differ from small to big each of the sound waves penetrates a certain amount of the bottom and because there are multiple blasts the noise of the blast cancel out the unwanted data. The sound wave the airguns generate are between 10 to 500 Hz in frequency and has a source level up to 232 dB compared to a transducer the rage is 16-210KHZ it is much lower

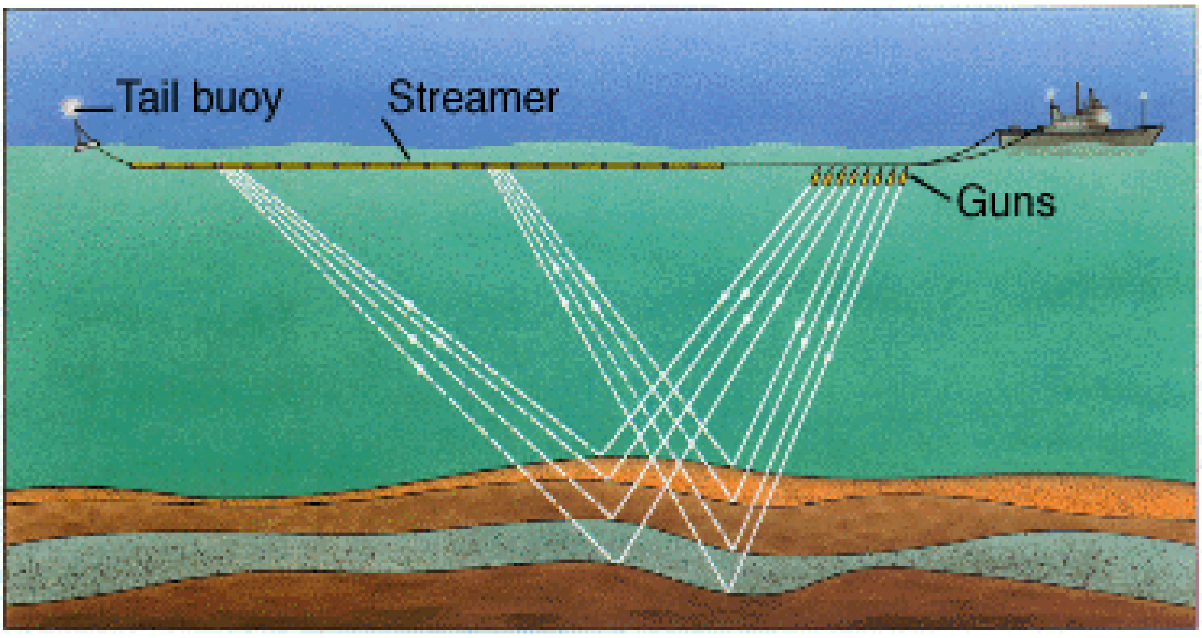

Figure 8 http://www.farallones.org/e_newsletter/2005-12/TroubledWaters.htm

Sound pulse

A sound pulse is a series of sound waves   which is given off by a vibrating material in the transducer. When the transducer is put under AC current it will start vibrating and giving of the sound pulse. When the sound pulse has reached the bottom, and is reflected the transducers pick-up the echo and changes it back in to an AC voltage. This sending, reflecting and measuring happens very fast but is dependable on the depth. This is because the sound pulse then must travel a greater distance.

Pulse repetition rate

This is the repetition rate of sound pulses in a specific time normally pulses per second. It is important to understand that the pulsate is not the same as the frequency. This is because a sound pulse does not always exist out of one sound wave but this depends on the frequency, wavelength, depth and sound velocity. Therefor the pulse repetition rate is almost always lower than the frequency. For example, is the wavelength is long then the frequency is low and there is a big depth and a slow sound velocity then the pulse duration is long and repetition rate is low. Because a surveyor cannot change anything from the depth or the sound velocity it must make other changes when the signal is returned this is mostly down by lowering the frequency which gives more power to the sound pulse. But when this is done the accuracy of the measurements also becomes lower. This also the case when only the power is enlarged.

The formula for pulse period: $T = \frac{1}{pulse\ repetition\ rate}$

And the formula for the range: $Range = \frac{c*T}{2}$

In these formula's

T= the pulse period in seconds

C= the sound velocity is meters per second

The sonar equation

During this assignment, I covered almost everything that is calculatable concerning sound but there is more thing that can be of use and is important to know and that the formula for signal excess also known as the echo of the soundwave the equation for this is called the sonar equation and goes as follow:

$$Signal\ Excess = SL - 2 * TL + BS - NL$$

SL=the source level

TL =the transmission loss

BS=the backscattering

NL=the Noise level

All in dB

The source level is as mentioned before, the transmission loss is the spreading loss plus the absorption loss. This means the duration the signal can travel before it is completely absorbed. Backscatter is the energy that is not absorbed by the sea-level thus it is the reflected sound wave and finally the noise level this the background noise which disturbed the echo of the signal and therefor make it harder to measure.

Sources:

The main source I used was the website:

http://www.dosits.org/

other sites included:

https://en.wikipedia.org/wiki/Sound

http://hyperphysics.phy-astr.gsu.edu/hbase/Sound/tralon.html